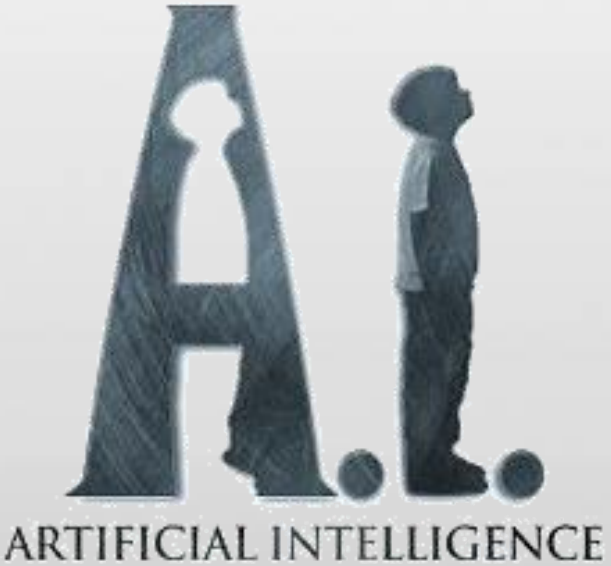

Logical Agents

Chapter 7

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Lecture outline

- Logical Agents
- Knowledge-Based Agents
- The Wumpus World
- Logic in general

Logical Agents

- “An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment though actuators” (Chapter 2)
- Consider representation of knowledge and reasoning process that brings knowledge to life

Logical Agents

- People know things and perform reasoning
- Knowledge of problem solving agents is very specific and inflexible
- Knowledge and reasoning are important in dealing with partially observable environments
- Sometimes hidden aspects of states must be inferred
- Knowledge based agents is flexible

Knowledge-Based Agents

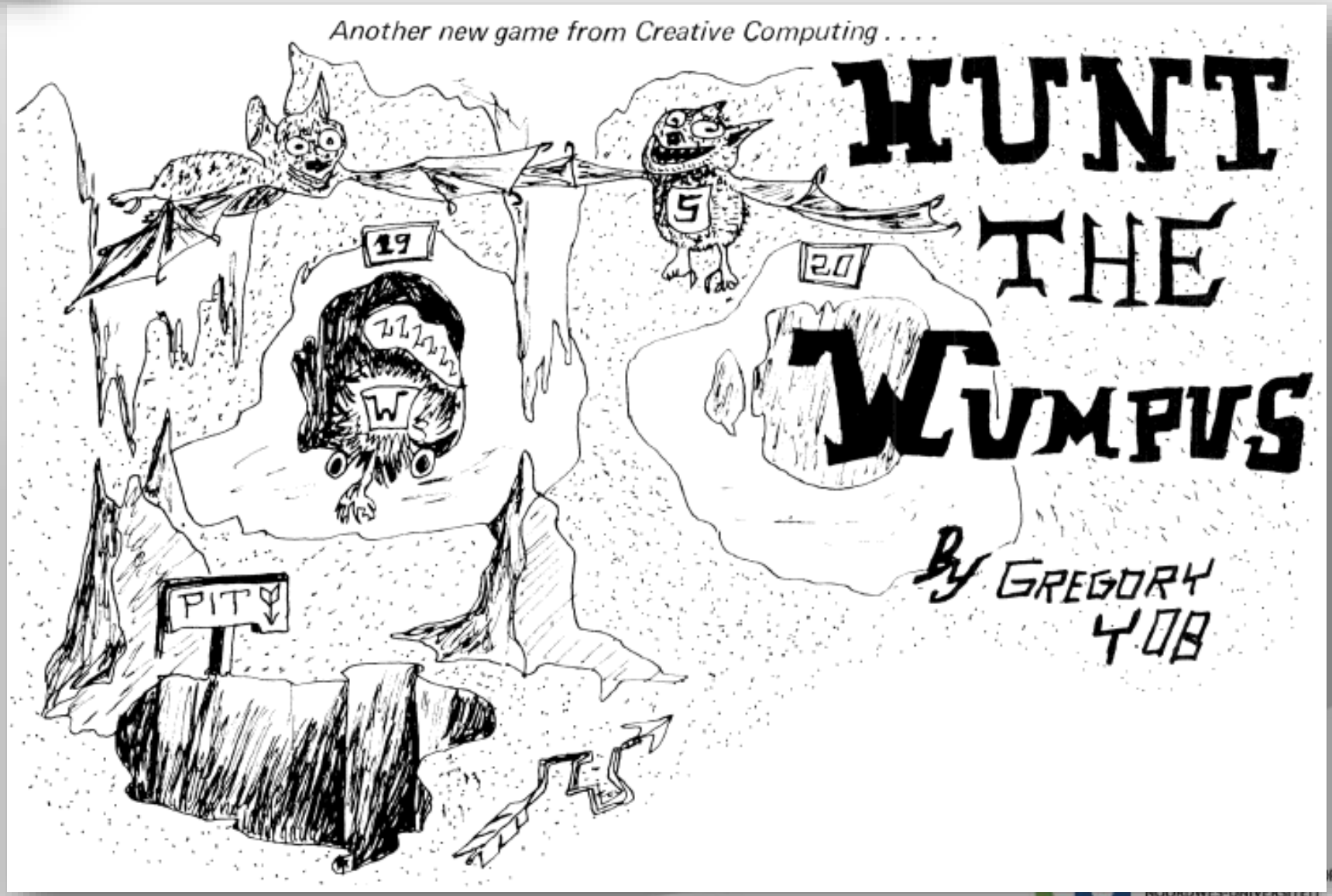
- Central component is knowledge base (KB)
- Knowledge base is a set of sentences
- Each sentence is expressed in a knowledge representation language
- TELL and ASK include inference
- Answers should follow logically from knowledge base

Knowledge-Based Agents

```
function KB-AGENT(percept) returns an action
    static: KB, a knowledge base
            t, a counter, initially 0, indicating time

    TELL(KB, MAKE-PERCEPT-SENTENCE(percept, t))
    action ← ASK(KB, MAKE-ACTION-QUERY(t))
    TELL(KB, MAKE-ACTION-SENTENCE(action, t))
    t ← t + 1
    return action
```

The Wumpus World



The Wumpus World

Another new game from Creative Computing . . . .

The Genesis of Wumpus

Two years ago I happened by People's Computer Company (PCC) and saw some of their computer games — such as Hurkle, Snark, and Mugwump. My reaction was: "EECH!!" Each of these games was based on a 10 x 10 grid in Cartesian co-ordinates and three of them was too much for me. I started to think along the lines of: "There has to be a hide and seek computer game without that (exp. deleted) grid!!" In fact, why not a topological computer game — Imagine a set of points connected in some way and the player moves about the set via the interconnections.

That afternoon in meditation the phrase "Hunt the Wumpus" arrived, and Wumpus was born. He's still a bit vague in physical detail as most dedicated Wumpus hunters know, but appearances are part of the game. (If you like, send me a picture of your version of a Wumpus. Perhaps friendly Dave, our editor, will publish the best one in *Creative Computing*.) The grid I chose was the vertices of a dodecahedron — simply because it's my favorite Platonic solid and once, ages ago, I made a kite shaped like one. The edges became the connecting tunnels between the caves which were the set of points for the game.

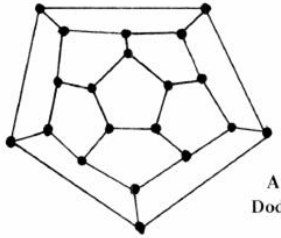
My basic idea at this time was for the player to approach the Wumpus, back off, and come up to him by going around the dodecahedron. To my knowledge, this has never happened . . . most players adopt other strategies rather than this cold-blooded approach.

Anyway . . . how to get the Wumpus! How about an arrow which could turn corners as it goes from room to room. Let the hunter tell the arrow where to go and let it fly. The shortest round trip without reversals is 5 caves — and thus the Crooked Arrow.

Hmmm . . . How does one sense the Wumpus? It's dark in yonder cave, and light would wake him up. If one got one cave away, the wumpus's distinct smell would serve as a warning. So far, so good . . . but Wumpus is still too easy, so let's find some appropriate hazards for the caves.

Bottomless pits were easy. Any imaginary cave would have a few of those around the place. Superbats were harder to come by. It took me a day or two to get that idea. The Superbats are a sort of rapid transit system gone a little batty (sorry about that one). They take you a random distance to a random cave and leave you there. If that's a pit or a Wumpus, well, you are in Fate's hands.

Around this time, I saw that Map-making would be a regular activity of Wumpus-hunters. I numbered the caves and made the scheme fixed in the hopes a practised player might notice this and make himself a permanent map of the caverns. (Another unrealised hope — as an exercise, make yourself such a map on a Squashed Dodecahedron).

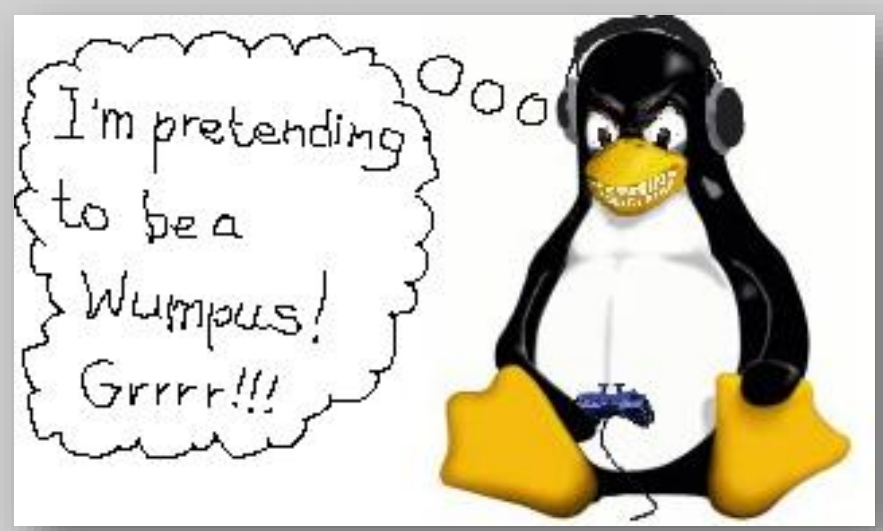


A Squashed Dodecahedron

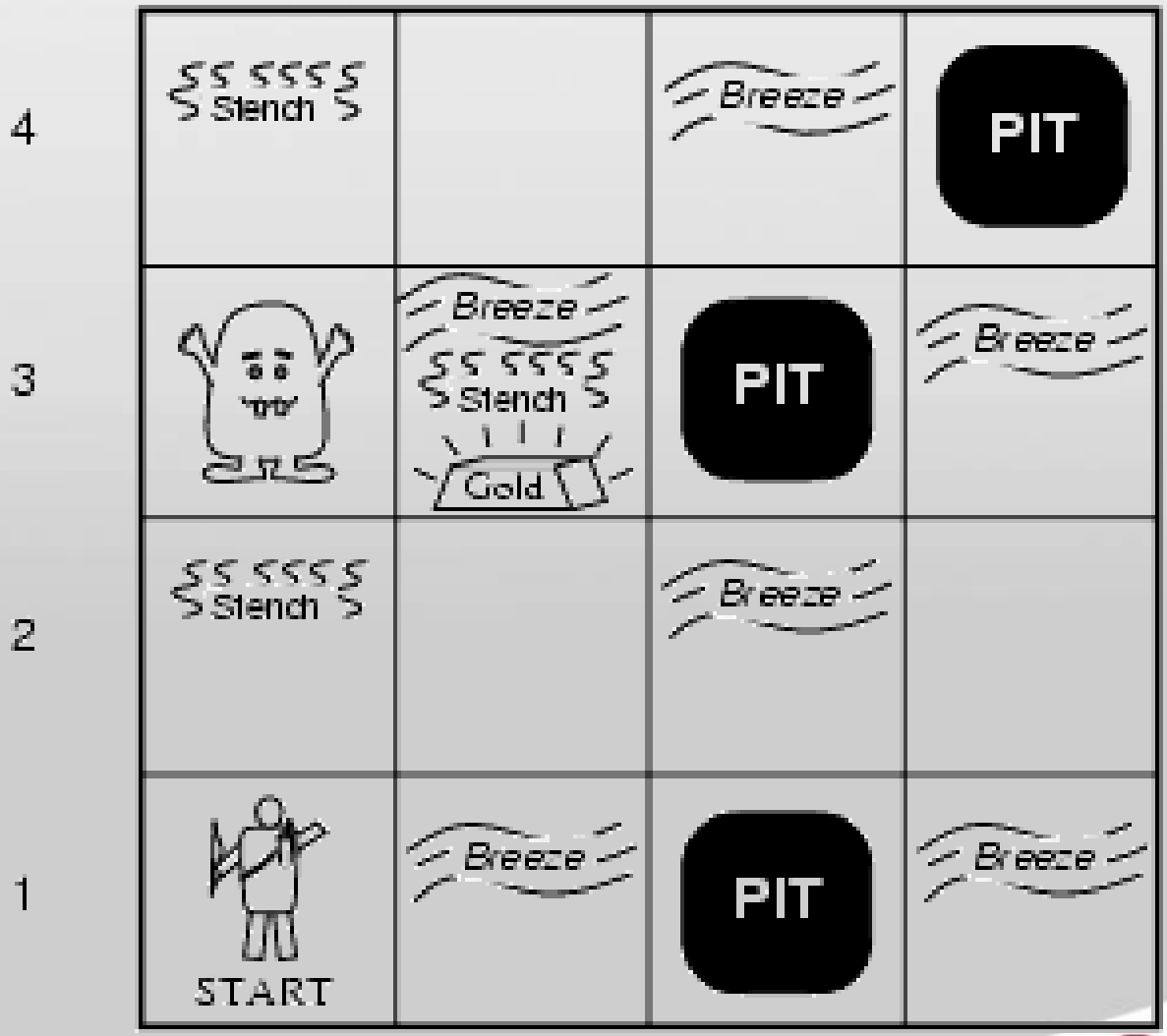
To start the game fairly, Wumpus, Hazards, and Hunter are located on different points at the start of the game. Each game starts with random choices of location, but the hunter may restart with the same set-up if he chooses. This allows re-plays if the hunter, say, fell into a pit on the first move.

Wumpus was nearly done in my mind . . . (hint to a games-writer: Have a clear notion of your game before you

The Wumpus World



The Wumpus World



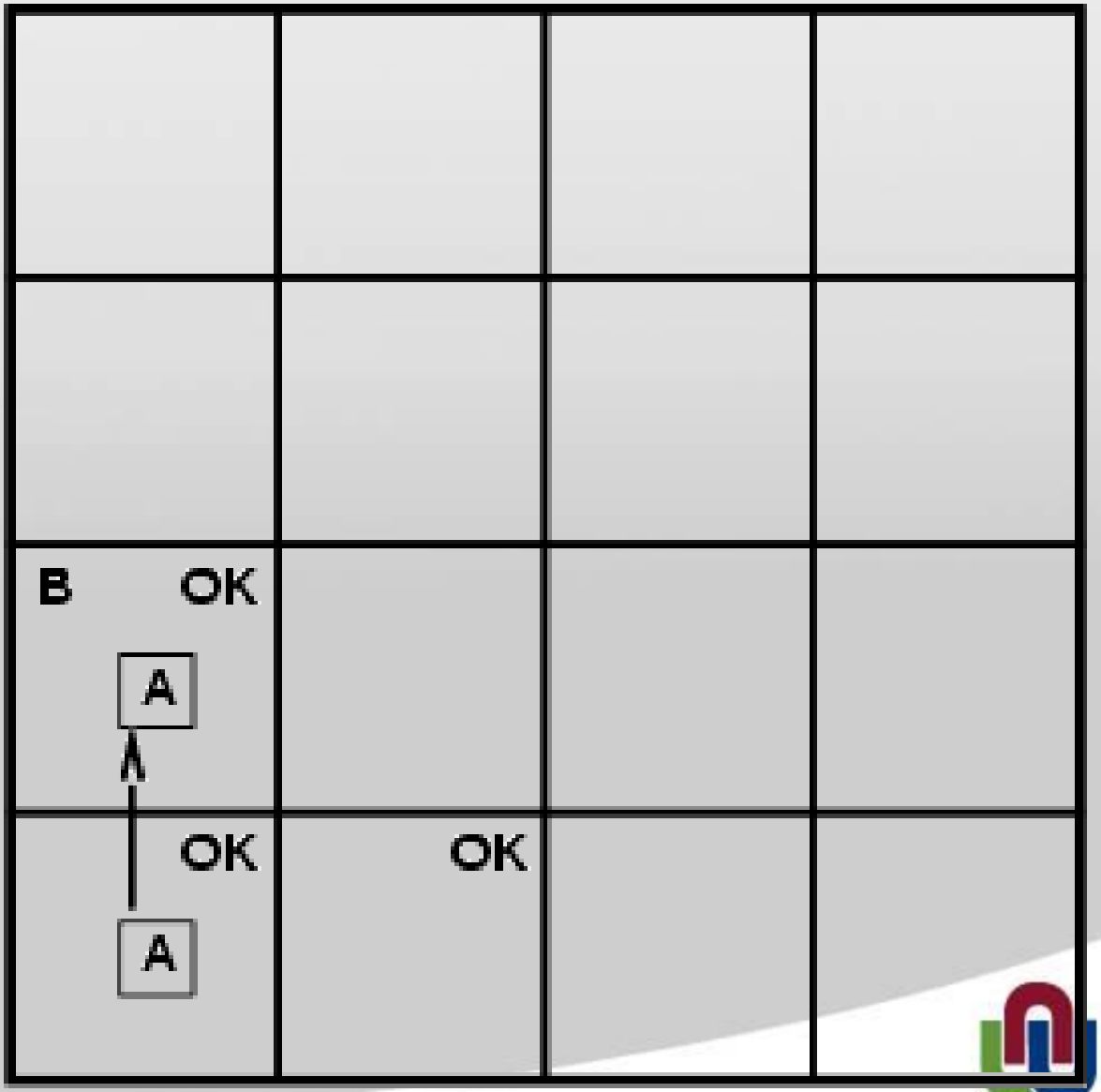
The Wumpus World

- Performance measure
- Environment
- Actions
  - Move, turn left, turn right, grab, shoot and climb
- Sensors
  - Stench, breeze, glitter, bump, scream
  - Example: [stench, breeze, none, none, none]

The Wumpus World

OK			
OK A	OK		

The Wumpus World



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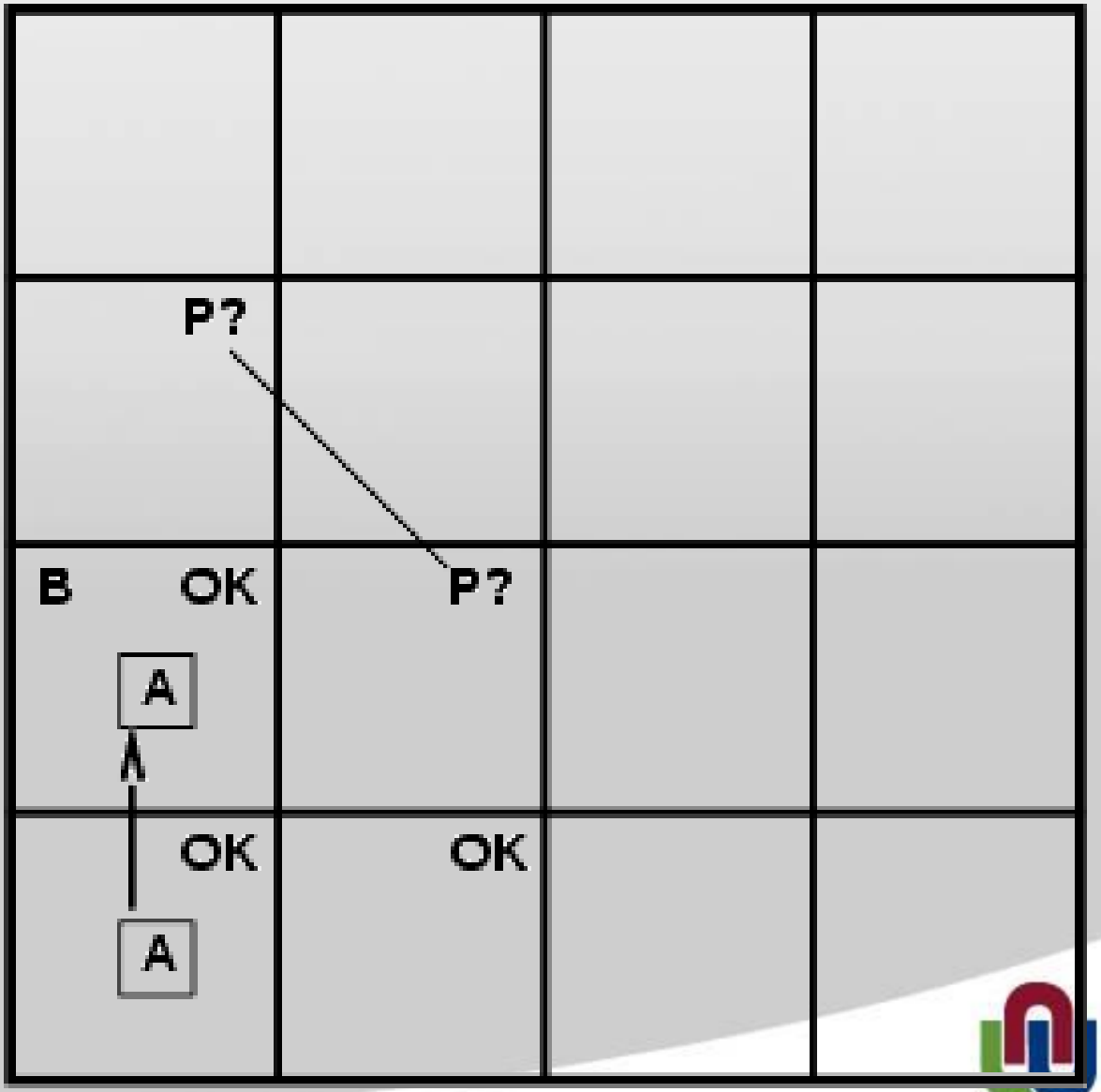

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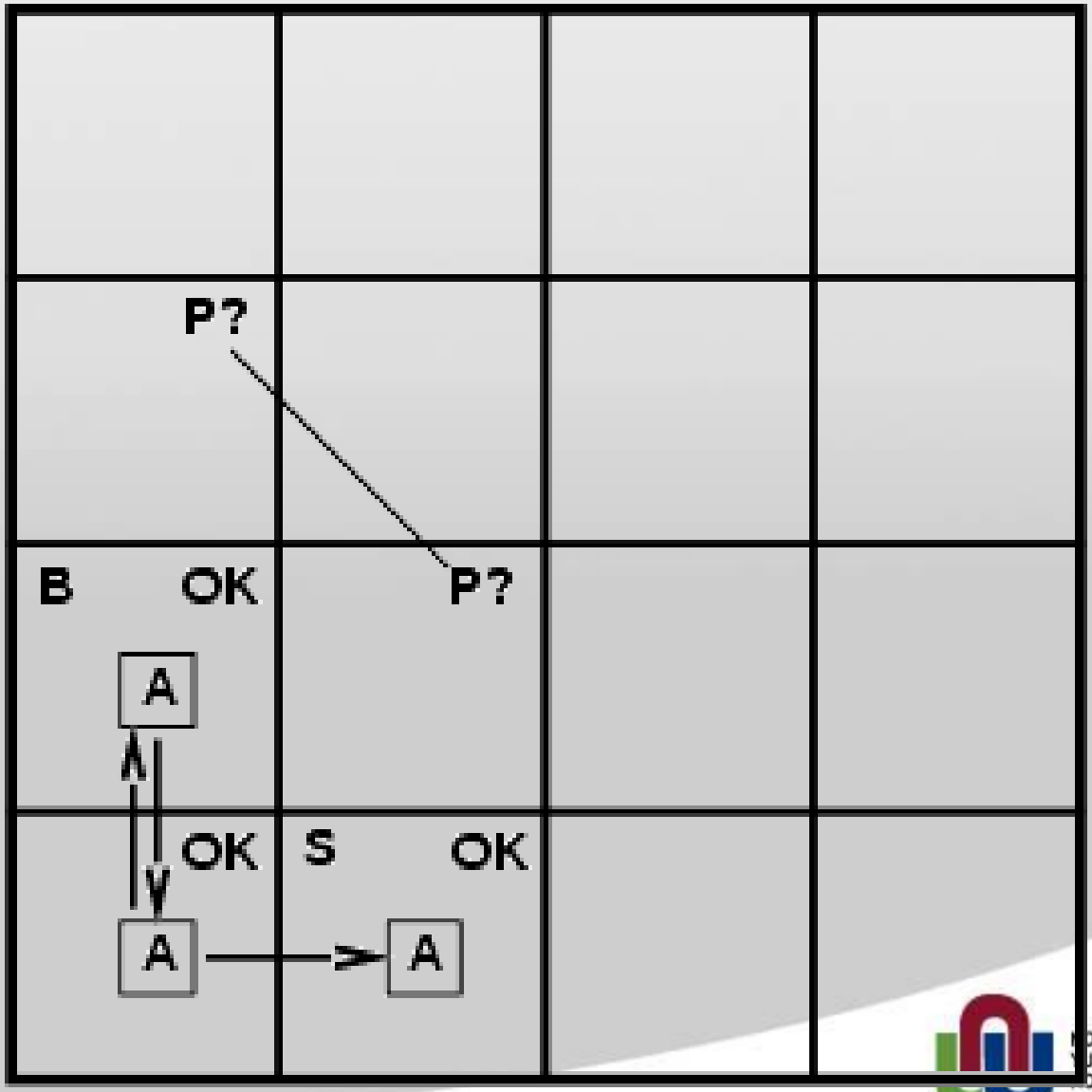
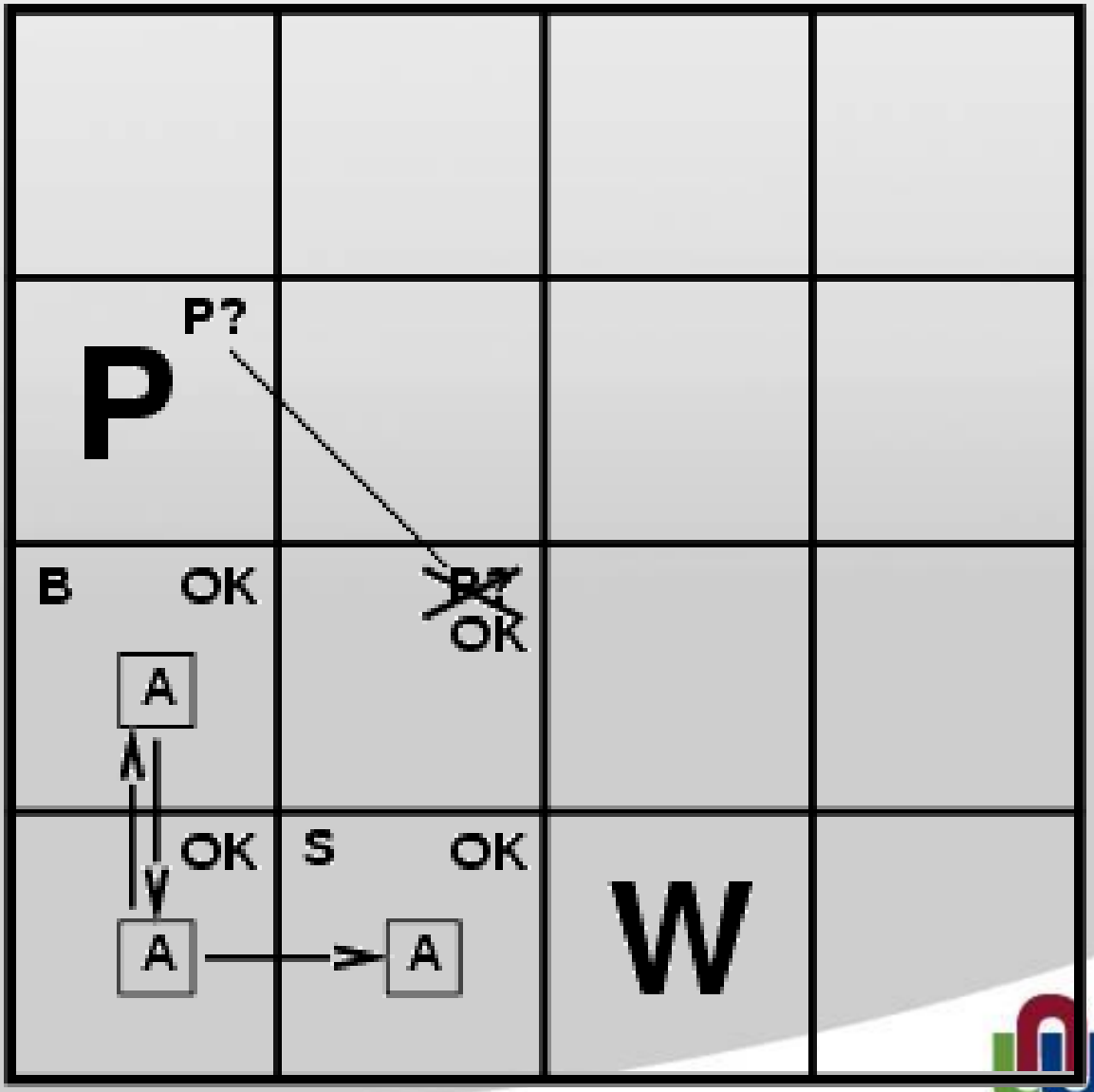


The Wumpus World



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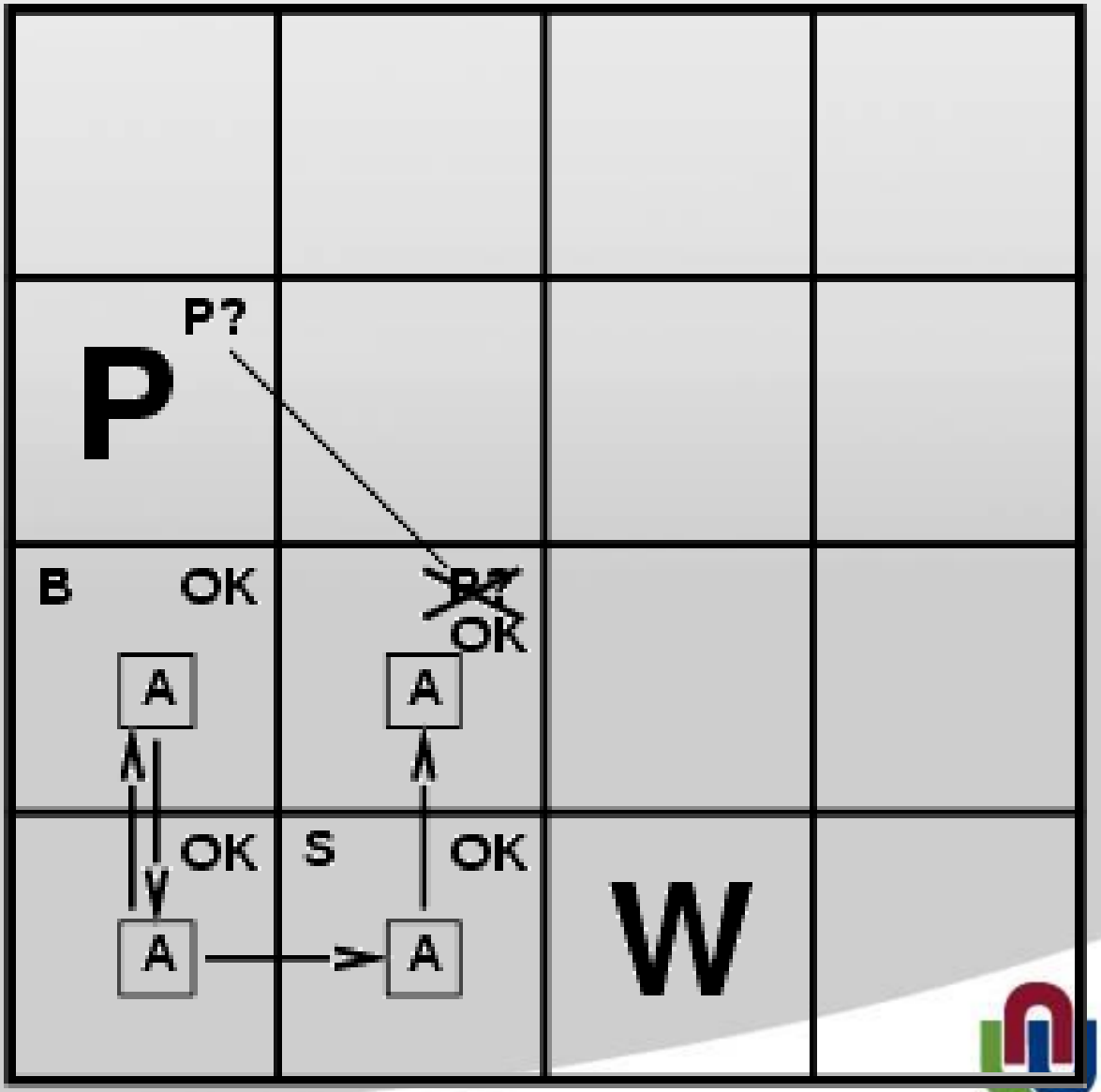

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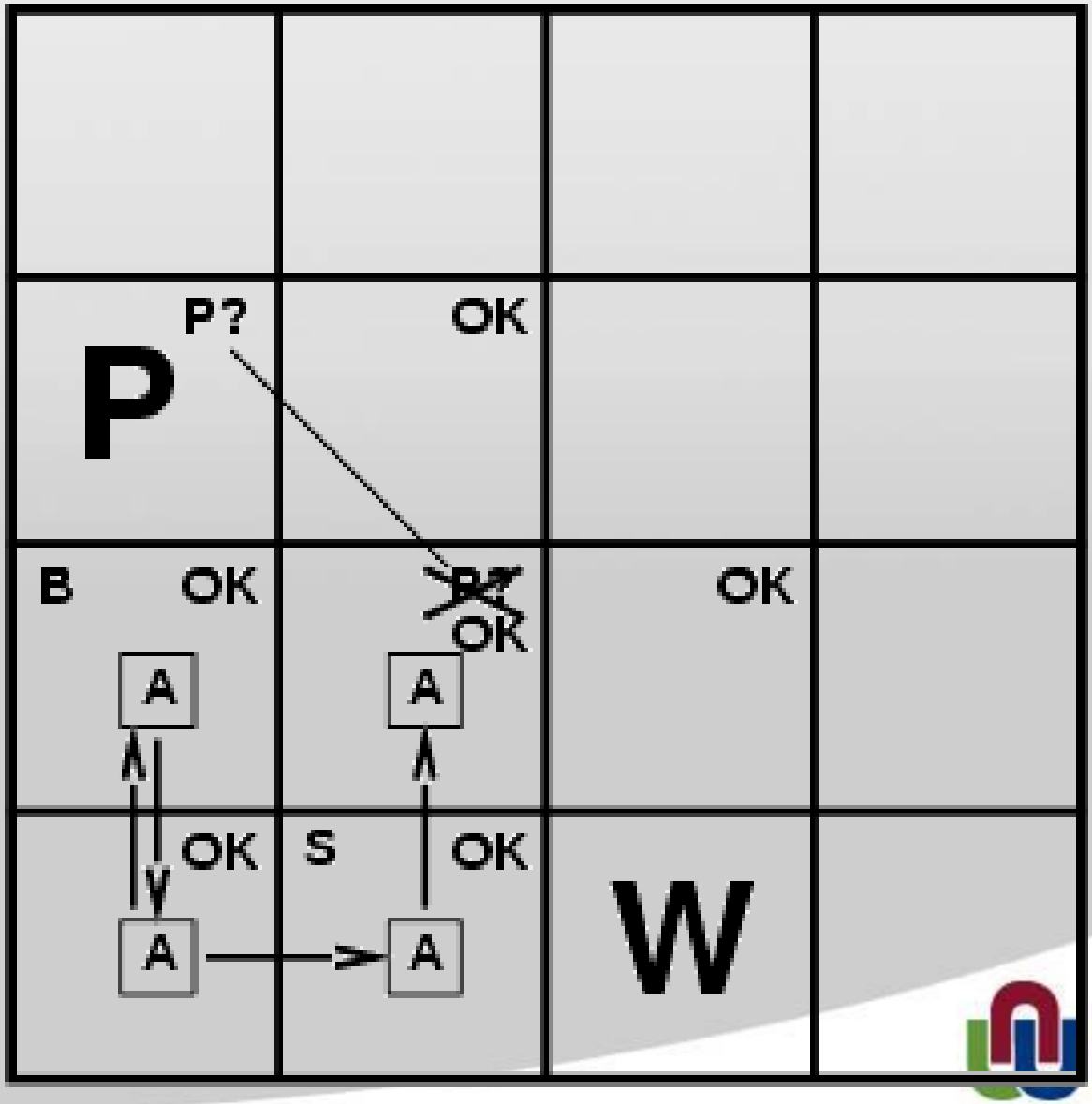
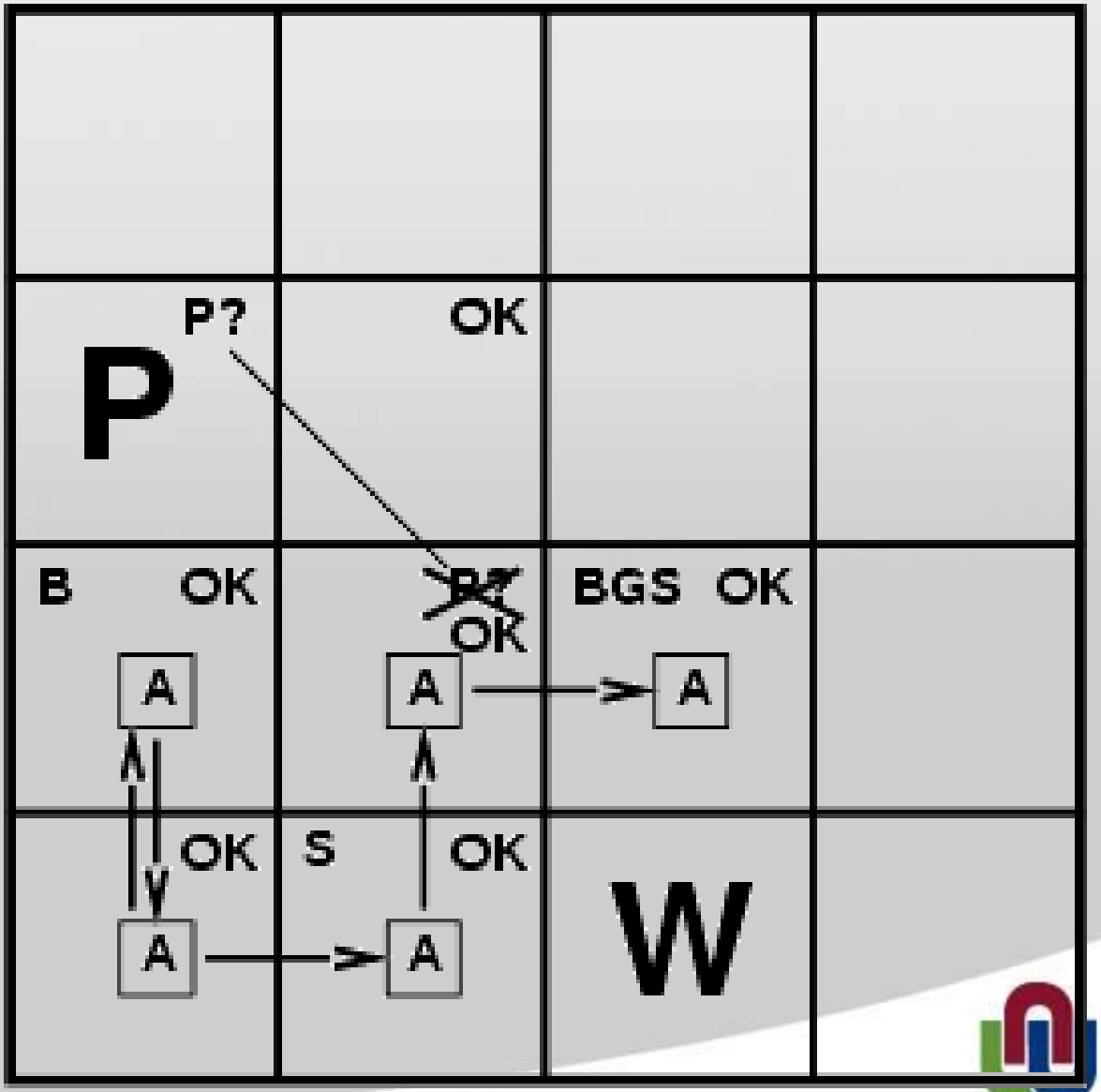


The Wumpus World



Logic in general

- Consider overview of logical representation and reasoning in general
- Knowledge base consists of sentences
- Sentences expressed according to syntax of representation language
- Example 1: $101x + 59y = 250$
- Example 2: *x 50 + - 90 z = y + =*

Logic in general

- Logics are formal languages to express information and reach conclusions
- Syntax defines sentences of the language
- Semantics defines the “meaning” of sentences
  - It is the truth of a sentence in each possible world
- In the language of e.g. arithmetic:

  $x + 2 \geq y$ is a valid sentence

  $x + 2 \geq \{\}$ is an invalid sentence

  $x + 2 \geq y$, true in a world where x = 7 en y = 1

  $x + 2 \geq y$, false in a world where x = 0 en y = 6

Logic in general

- Use “model” instead of “possible world”
- A model determine the truth or falsity of each relevant sentence

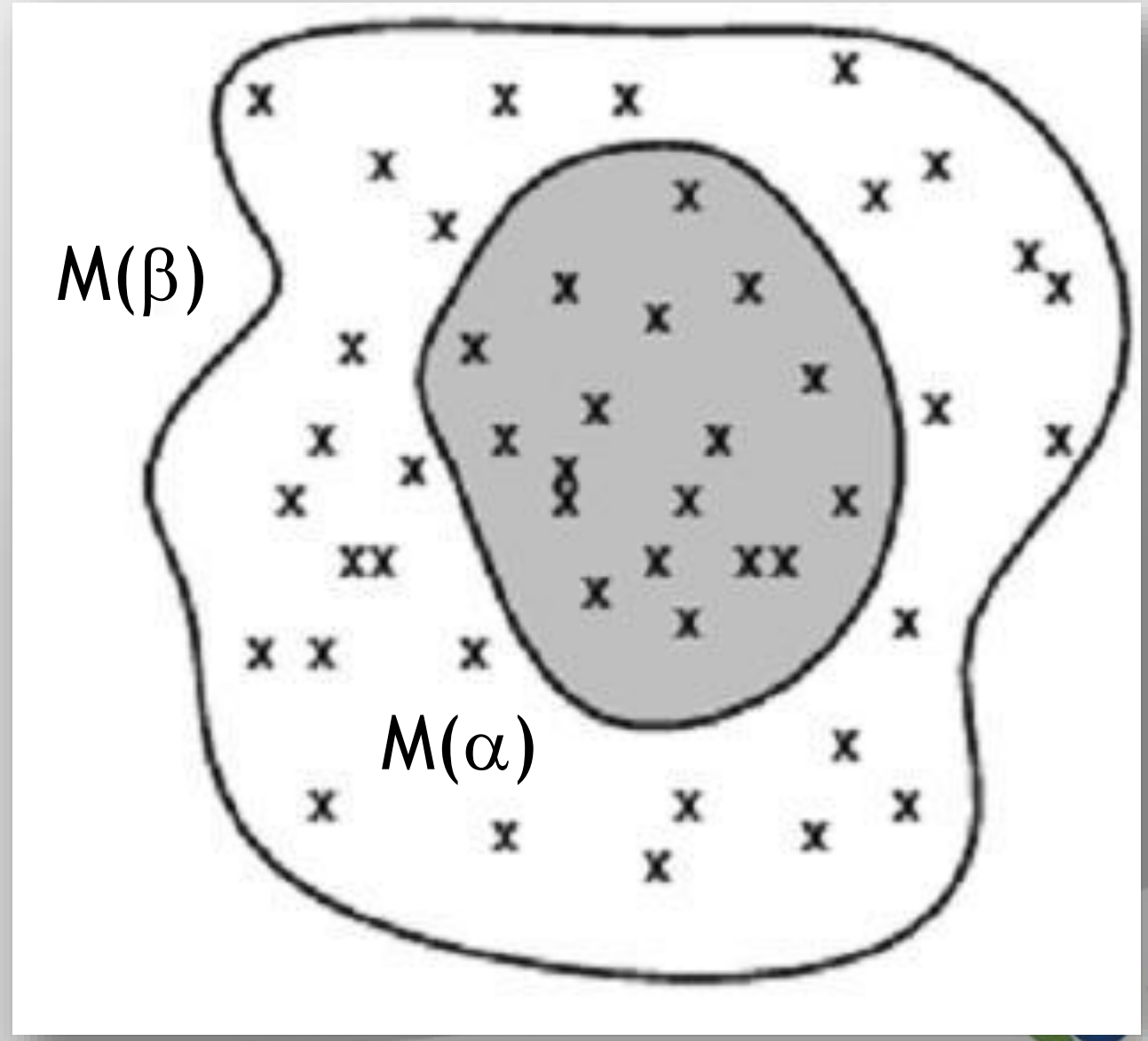
Models

- A logician thinks in terms of models
- Models are formal structured worlds out of which truth can be evaluated
- We say *m* is a model of sentence α if α is true in *m*
- M(α) is the set of all models of α

Logical entailment

- Entailment means one sentence follows logically from another: $\alpha \models \beta$
- Sentence β follows logically from sentence α if and only if β is true in all models (worlds) where α is true
- $\alpha \models \beta$ if and only if $M(\alpha) \subseteq M(\beta)$
- Ie. β follows logically from α if the set of models of α is a sub-set of the set of models of β

Models



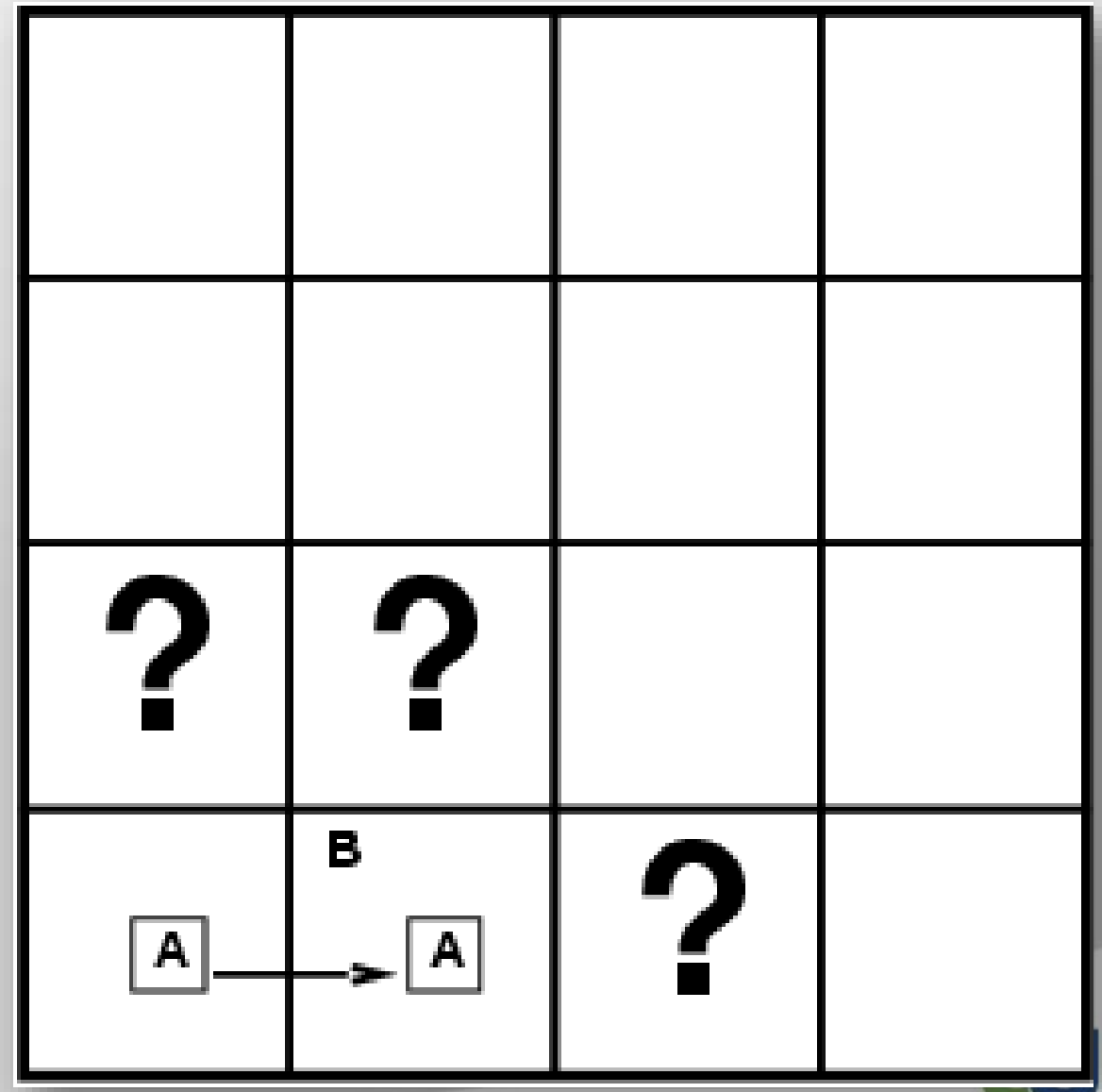
Logical entailment

- Is the following statement true?

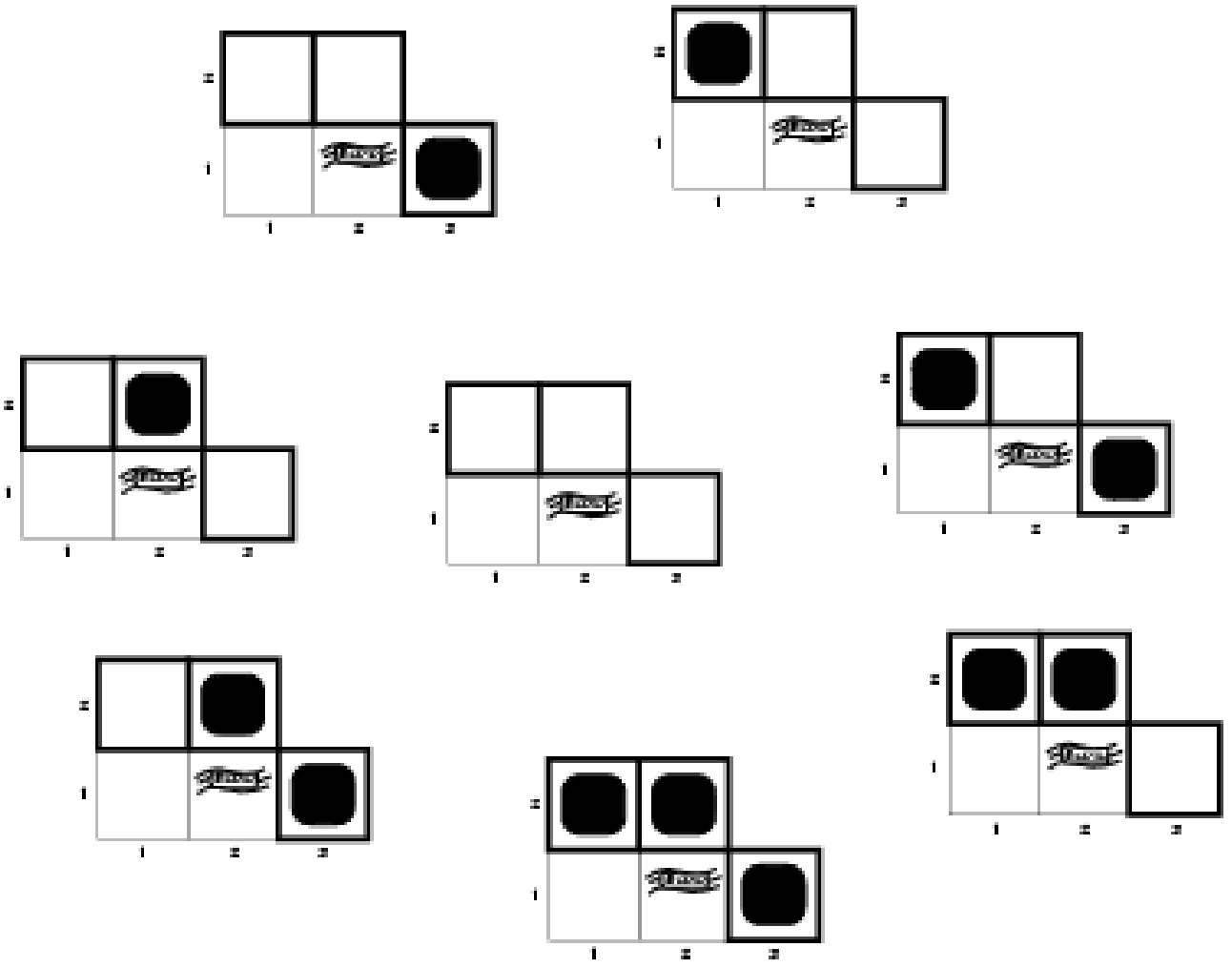
  $4 = x + y$ follows logically from $x + y = 4$

- Entailment is a relationship between sentences (i.e. syntax) based on semantics

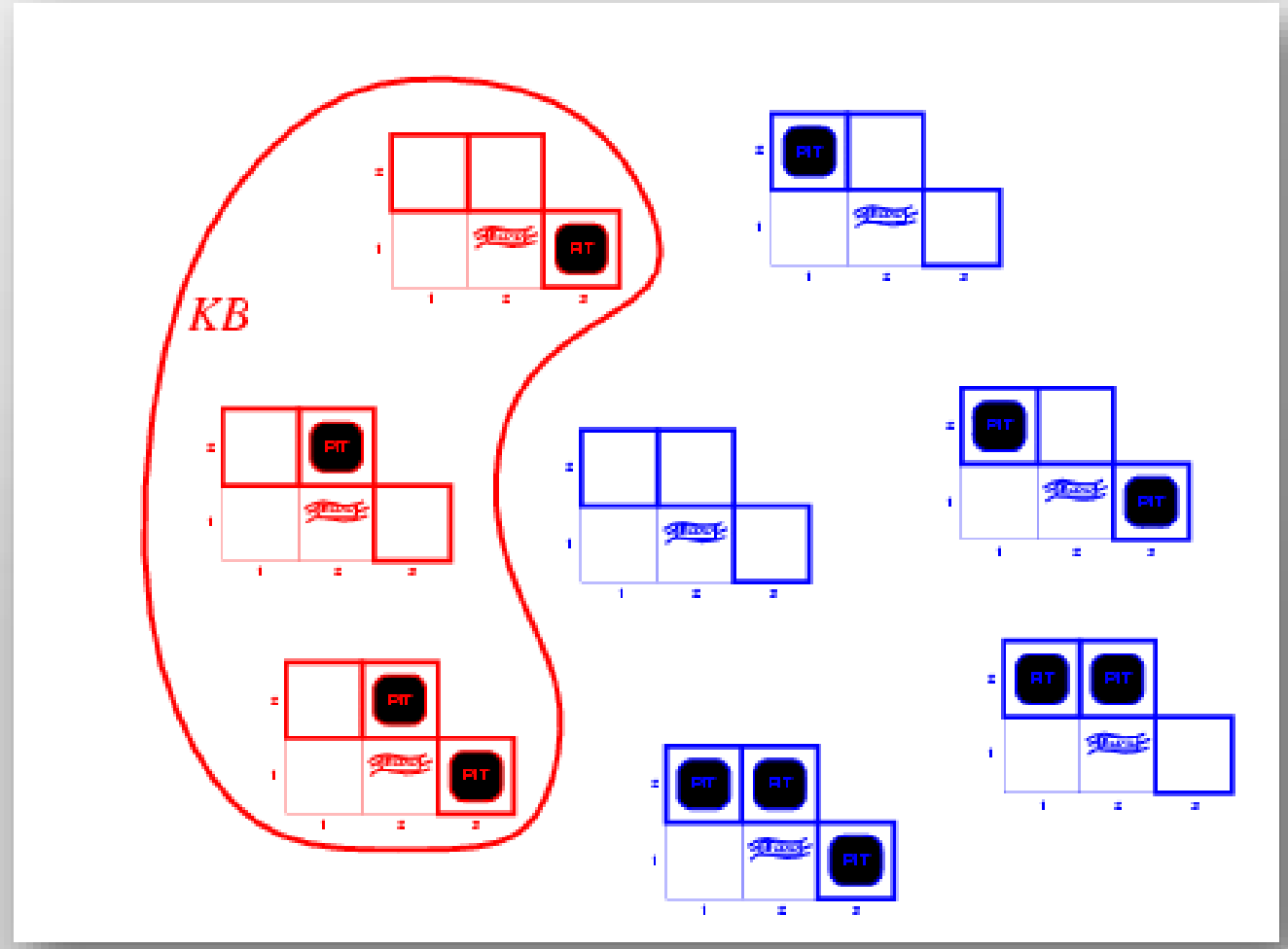
Entailment in Wumpus world



Wumpus models

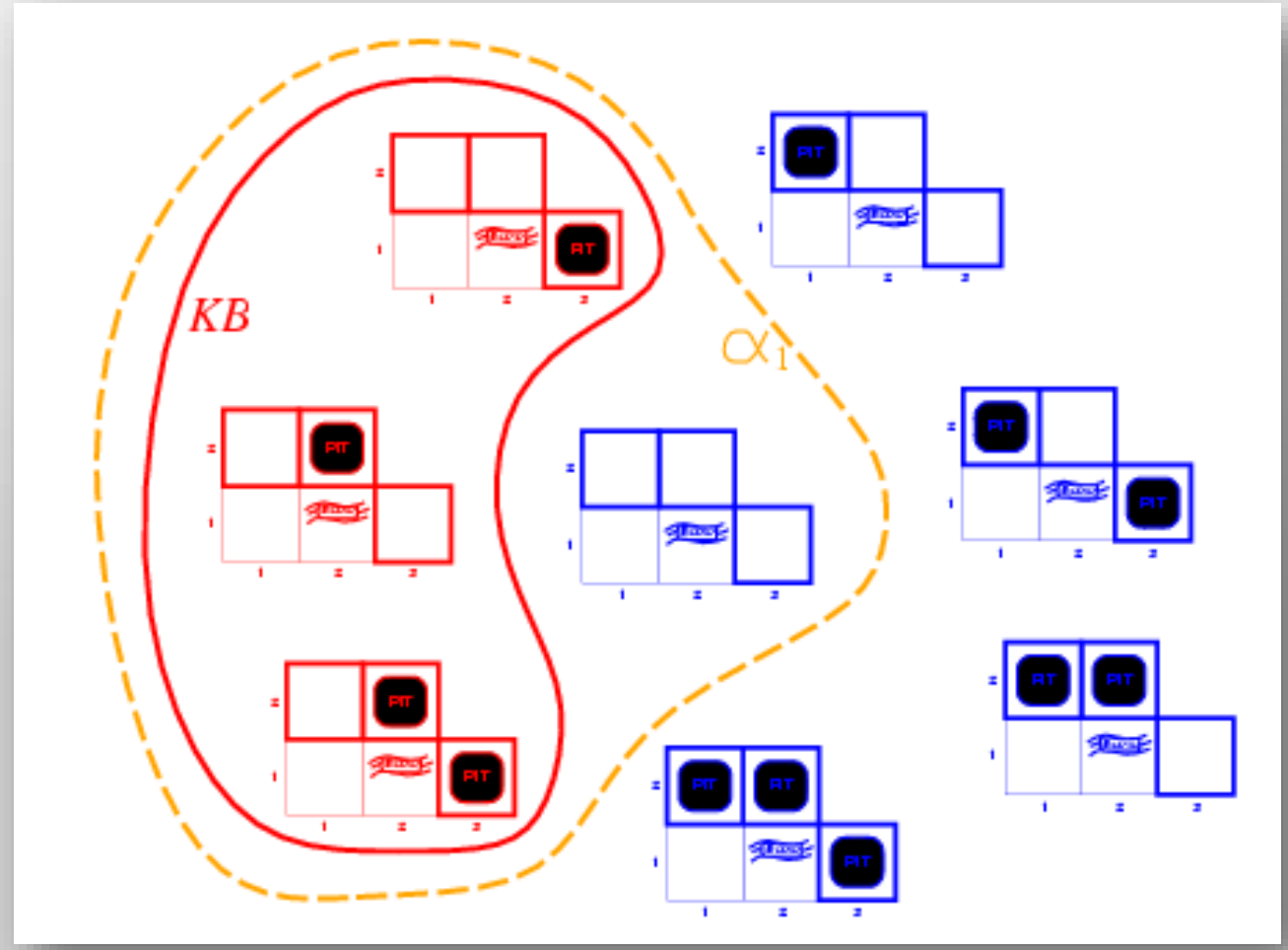


Wumpus models



KB = Wumpus world rules
+ perceptions

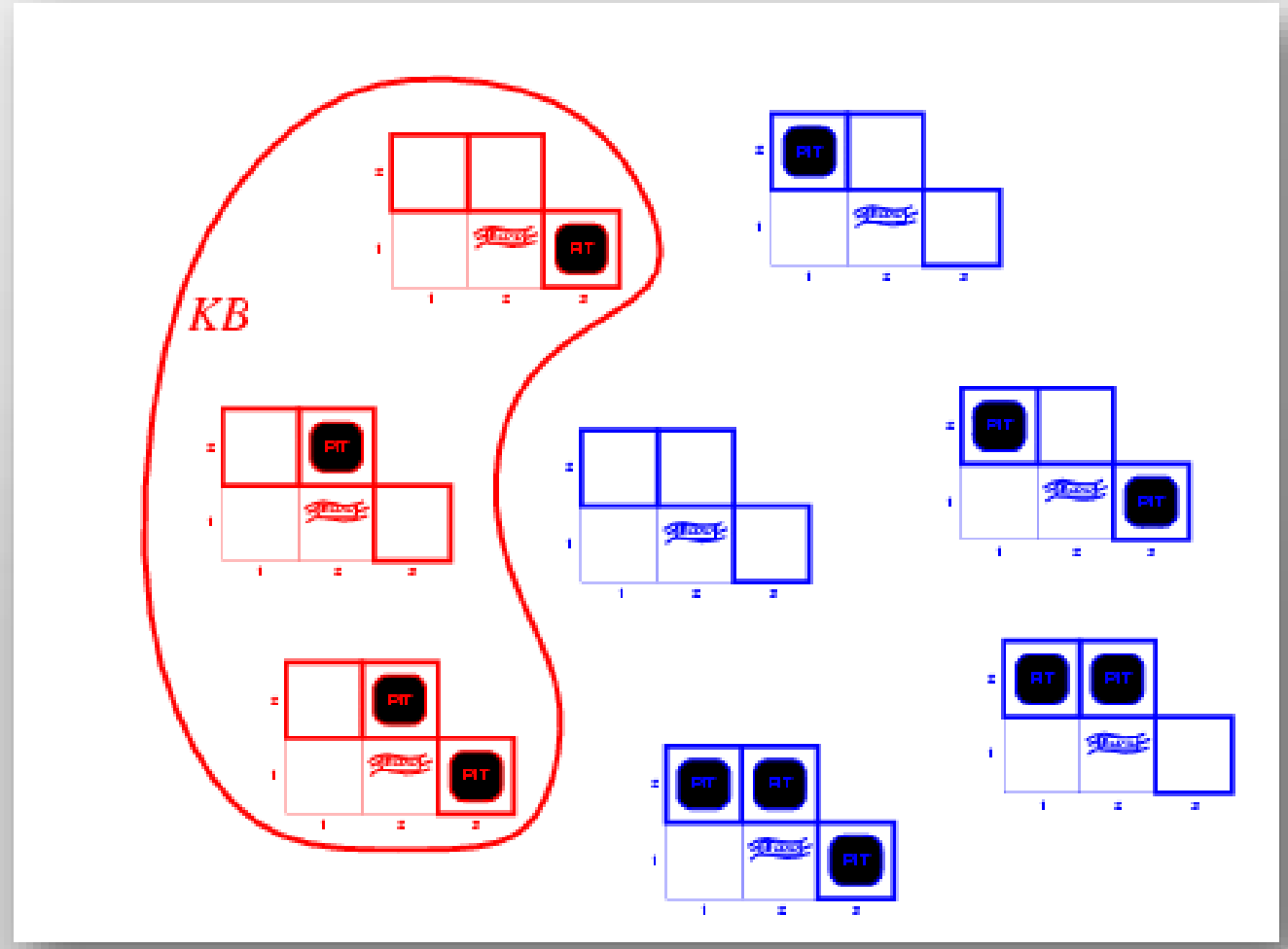
Wumpus models



KB = Wumpus world rules + perceptions

α_1 = "[1,2] has no pit", KB $\models \alpha_1$

Wumpus models



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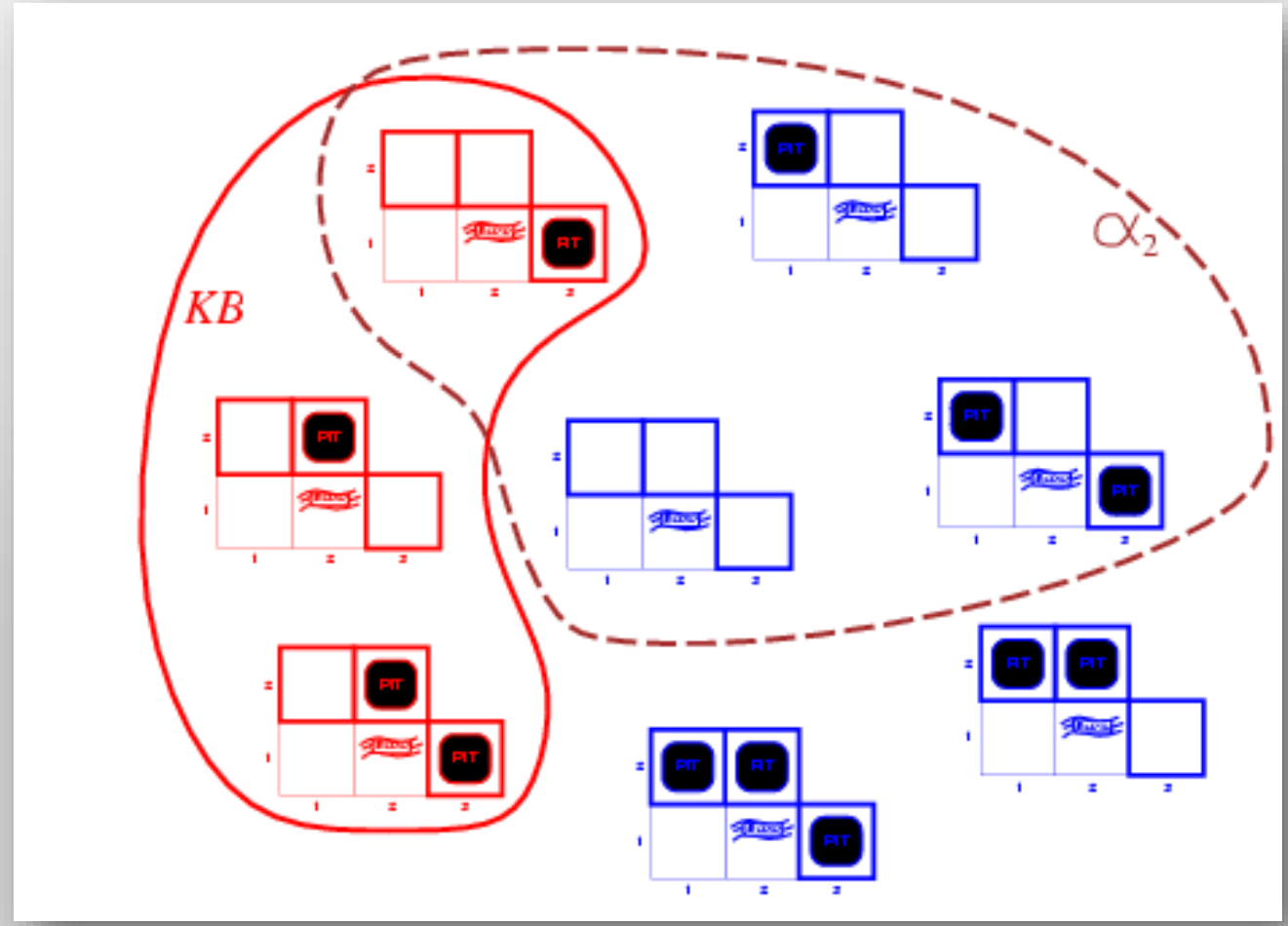
Wumpus models



KB = Wumpus world rules + perceptions

α_2 = "[2,2] has no pit", KB $\not\models \alpha_2$

Inference

Inference

- KB $\vdash_i \alpha$ means sentence α can be derived from KB by procedure *i*
- Soundness: procedure *i* is sound if KB $\vdash_i \alpha$, then KB $\models \alpha$
- Completeness: procedure *i* is complete if KB $\models \alpha$, then KB $\vdash_i \alpha$
- Later we define a logic (first-order logic) that has a sound and complete proof procedure

Assignment

- Please study today's work
- Complete practical assignment 1 for Thursday, 19 August 2021
- Study for a multichoice quiz on today’s work for Thursday, 19 August 2021